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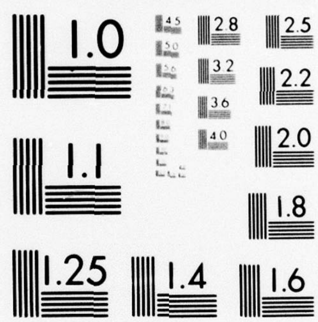

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A retrospective study of F-4 ejections from 1967-77 revealed extremity injuries during the ejection sequence in 43 of 399 ejections for an injury rate of 10.8%. Of the 43 ejections there were 95 extremity injuries. The injuries were divided into two groups: Severe and Minimal. Severe injuries consisted of fractures, dislocations, ligamentous tears and nerve palseys. There were 61 severe injuries. Minimal injuries consisted of contusions, lacerations, minor sprains. There were 34 minimal injuries. The 61 severe injuries were divided into 39 upper extremity injuries and 22 lower extremity injuries. The majority of the severe upper extremity injuries involved the proximal joints and the majority of the severe lower extremity injuries involved the distal joints. When the windblast/windflail injuries were compared to the various variables correlation (Continued)

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20. Continued: was seen with the Knots Indicated Airspeed (KIAS), aircraft attitude and aircraft type. The incident of extremity injury increases with increased airspeed, a nose down attitude, and decreases in the RF-4C aircraft configuration.

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CORRELATION OF MECHANISM OF EXTREMITY INJURY AND AERODYNAMIC FACTORS IN EJECTIONS FROM F-4 AIRCRAFT

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A retrospective study of F-4 ejections from 1967-77 revealed extremity injuries during the ejection sequence in 43 of 399 ejections for an injury rate of 10.8%. Of the 43 ejections there were 95 extremity injuries. The injuries were divided into two groups: Severe and Minimal. Severe injuries consisted of fractures, dislocations, ligamentous tears and nerve palseys. There were 61 severe injuries. Minimal injuries consisted of contusions, lacerations, minor sprains. There were 34 minimal injuries. The 61 severe injuries were divided into 39 upper extremity injuries and 22 lower extremity injuries. The majority of the severe upper extremity injuries involved the proximal joints and the majority of the severe lower extremity injuries involved the distal joints. When the windblast/windflail injuries were compared to the various variables correlation was seen with the Knots Indicated Airspeed (KIAS), aircraft attitude and aircraft type. The incident of extremity injury increases with increased airspeed, a nose down attitude, and decreases in the RF-4C aircraft configuration.

The problem of extremity injury during emergency escape in the open seat ejection has been a continuing one and has received considerable attention over the past decade. Reports by Fryer and Payne, and by Hawker have shown extremity injury rates resulting from wind flail forces to range from 7% to 9%. The extremity injury rate under combat conditions has risen to 25%. Based upon these data, it was decided that a retrospective study should be conducted on F-4 ejectees. Its purpose was to: (a) identify the musculoskeletal regions most susceptable to windblast/windflail forces, (b) identify the modes and severity of trauma, and (c) speculate on the biomechanics of motion required to produce the injury mode observed. Initially, all the accident reports that listed an extremity injury for F-4 ejections at the Air Force Inspection and Safety Center, Norton AFB, CA, were carefully reviewed with respect to aircrew/seat anthropometry, aerodynamic conditions, ejection seat type, and the site, type, and time of occurrence of injury during the ejection sequence.

The anthropometric data consisted of the aircrewmen's height, weight, age, trunk height, sitting height, leg length, knee-buttock length, and shoulder diameter; aerodynamic data culled included Knots Indicated Airspeed (KIAS), aircraft attitude, altitude AGL and/or MSL, and aircraft type. The ejection seat data consisted of ejection seat type, history of modification, inertia reel type, restraint harness type, mode of ejection initiation, and seat and body position at ejection. The injury data consisted of the type and location of the injury, the number of days grounded and hospitalized, and the results of any radiographs taken. The reports were also screened for severity of parachute opening shock, parachute oscillations, landing terrain, and previous ejections or emergency parachute jumps.

These preliminary findings indicated that of the 399 noncombat F-4 ejections for this time period, there were 43 ejectees who sustained long bone and/or joint trauma that could be attributed to emergency escape sequence. These statistics did not include injuries that were ascribable to parachute landing kinematics. Based upon these data, the extremity injury rate for the decade under study was 10.8%.

Letters were written to the respective medical centers, and post-ejection radiographs and clinical records were retrieved. Based upon clinical and radiographic materials, the injuries were classified as either severe or minimal injuries. Severe injuries were identified as long bone fractures and dislocations, ligamentous injuries, and nerve palseys. The ligamentous injuries were those requiring either surgical repair or prolonged immobilization over one week including meniscal tears. The nerve palseys were either permanent or the temporary ones that lasted more than one day. The severe injuries required more than one week loss from duty. The minimal injuries included: (1) contusions with or without bruising that required no immobilization and resolved in 2 days, (2) lacerations which did not include tendons, major arteries, motor nerves, or compound fractures, (3) sprains (a ligamentous injury that does not cause incontinuity of the ligament) which required no more immobilization than an elastic bandage and did not prevent the aircrewmen from returning to duty.

In all, there were 95 extremity injuries recorded for the 43 ejections studied. Of these, 61 were identified as severe injuries and 34 were minimal injuries. The severe injuries could be further broken down into 39 injuries of the upper extremity and 22 injuries of the lower extremity.

The severe upper extremity injuries consisted of 25 shoulder, 9 elbow, 3 forearm, and 2 hand injuries. These were attributable to the following forcing functions with respect to the ejection sequence with injury number listed in parenthesis: (a) retraction [1], (b) rocket catapult ignition [6], (c) windblast and windflail [32].

A single retraction injury was found. It consisted of a fracture of the midshaft of the clavicle that was the result of the inertia reel forces during the retraction sequence of the restraint harness shoulder strap.

The six injuries occurring during rocket catapult ignition are listed along with their mechanisms of injury:

(1) Midshaft ulnar fracture caused by a blow to the ulnar side of the forearm most likely the result of violent contact with sill.

(2 & 3) A transverse fracture of the humerus with a median nerve palsey caused by a blow to the midarm by the cockpit sill secondary to a midair collision.

(4) A compound midforearm fracture caused by the arm striking the idler push-pull rods during an inadvertent ejection.

(5) An ulnar styloid fracture caused by a blow to the dorsal ulnar side of the wrist by the console.

(6) Intraarticular thumb metacarpalphalangeal (MCP) joint fracture caused by a blow to the ulnar side of the distal thumb due to forceful interaction with the throttle.

The 32 windblast/windflail injuries are listed below with the mechanism of injury:

(1) 3rd, 4th, and 5th metacarpal fractures caused by the arm flailing and striking either the seat or personnel equipment.

(2 & 3) Fractured ulnar coronoid process and median nerve palsey secondary to elbow hyperextension.

(4) Posterior elbow dislocation caused by hyperextension of the elbow.

(5-8) Posterior elbow dislocation and proximal ulnar fracture caused by hyperextension of the elbow.

(9 & 10) Humeral supracondylar fracture caused by hyperextension of the elbow.

(11) Midshaft humeral fracture caused by abduction of the arm and striking the seat or from violent muscular contraction in an attempt to control the arm.

(12-17) Proximal humeral fractures; i.e., greater tuberosity or humeral neck fractures, with tears of the long head of the biceps tendon or median nerve palsey caused by hyperabduction of the arm.

(18) Shoulder dislocation, an anterior subglenoid type, caused by hyperabduction of the arm.

(19-26) Shoulder dislocation with proximal humeral fracture caused by hyperabduction of the arm.

(27-29) Glenoid fractures associated with dislocated shoulders which were spontaneously reduced, caused by hyperabduction of the arm with or without external rotation of the arm.

(30-32) Scapular fractures of the spine and neck caused by a blow to the scapula or by hyperabduction of the arm.

From this review, it is apparent that the severe upper extremity injuries were proximal involving the elbow and shoulder. The elbow severe windflail injuries occurred secondary to the hyperextension of the elbow. The shoulder severe windflail injuries occurred secondary to hyperabduction of the shoulder.

The 22 severe injuries of the lower extremities consisted of 2 ankle, 7 calf, 10 knee, 2 thigh, and 1 hip injury. These could also be classified by when they occurred during the ejection sequence: retraction (4), seat ejection (3), and windflail (15).

The four injuries occurring during retraction are listed with their mechanism of injury:

(1-4) Spiral fractures of the proximal fibula caused by a blow to the fibular head by dual leg garter configuration.

The three injuries occurring during seat ejections are listed with mechanism of injury:

(1 & 2) Tibial plateau fracture with transverse fibular fracture occurring from a blow to the lateral side of the knee secondary to a midair collision.

(3) A compound tibial-fibular fracture caused by entanglement of the WSO's (Weapons Systems Operator) foot and leg in the pilot's deployed parachute.

The fifteen injuries occurring during windflail are listed with their mechanism of injury:

(1) Lateral subtalar dislocation with fracture of the anterior calcanel facet caused by external rotation of the foot.

(2) Medial malleolar fracture caused by external rotation and eversion of the foot.

(3 & 4) Compound comminuted tibial fibular fracture caused by external rotational forces applied to the foot and calf.

(5 & 6) Internal derangement of the knee, a nebulous diagnosis but usually a torn meniscus, anterior cruciate ligament, medial collateral ligament or capsule, subsequently diagnosed as a torn medial collateral ligament with the mechanism of injury being external rotation of the foot and calf.

(7-10) Medial collateral ligament tears caused by external rotation of the foot and calf, which may also be accompanied by a valgus moment of the foot and calf.

(11) Medial collateral ligament and anterior cruciate ligament tear caused by a forced external rotation-valgus moment of the foot and calf.

(12) Knee dislocation with a torn medial meniscus and medial collateral ligament caused by a violent external rotation force applied to the foot and calf.

(13 & 14) Comminuted fractures of the midshaft of the femur most likely caused by torque applied to the distal femoral shaft.

(15) Posterior rim of the acetabulum fracture that could result from a direct blow to the knee with the hip flexed to 90° or by marked external rotation of the leg forcing the femoral head against the posterior rim of the acetabulum.

From reviewing the mechanism of severe windflail injuries of the lower extremity, all are the result of excessive external rotation.

The majority of the ejections involved the Martin-Baker H7 seat (34 of 43). The rest (9 of 43) involved the Martin-Baker H5 ejection seat. The severe windflail injury rate for the ejections studied from these two seats is 45.5% for the H5 and 47.1% for the H7.

A review of the anthropometric data shows no significant difference between the minimal and severe windflail injury groups for all parameters studied.

A comparison of the KIAS (Knots Indicated Airspeed) between the severe windflail group and the minimal injury group revealed an average KIAS of 403 knots for the severe group and 310 knots for the minimal injury group.

In analyzing the severe injury group, it was noted that the majority (94%) occurred in a nose down attitude as compared to 54% for the minimal injury group. If the attitude of $\pm 10^\circ$ nose down is considered, the severe injury group rate was 92% as compared to only 14% for the minimal injury group. Examination of the two ejections that compromise this 14% for the minimal injury group revealed: (1) an YRF-4C modified aircraft with a large CRT display and console present with the ejection occurring at 10° nose down at 550 KIAS by the WSO after an ejection by the pilot (a reversal of the normal ejection sequence) at 20° nose up at 600 KIAS, and (2) an RF-4C at 10° nose down but flying at only 150 KIAS. The study of these ejections helps highlight the fact that ejections of 10° or greater nose down at KIAS over 200 knots will most likely result in extremity injury.

A comparison of aircraft types showed that the RF-4C group had only a 35% severe extremity injury rate while the rest of the F-4 C, D, E's has a 76% severe extremity injury rate. Since the ejection and restraint systems, aircrewmen and aerodynamic factors are comparable for both groups, the difference is most likely the reconnaissance configuration of the RF-4C, especially the longer nose and anterior oblique camera blister.

From this study it can be seen that the majority of extremity injuries are windflail injuries (77%). The windflail injuries occur at the higher speeds 403 knots as compared to 310 knots, in a nose down attitude 92% as compared to 14%, and more frequently in F-4C, D, F aircraft 76% as compared to the RF-4C 35%.

The mechanism of injury in the windflail injuries was one of hyperextension of the elbows, hyperabduction of the shoulders, and external rotation with or without valgus moment in the legs.

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